

National Aeronautics and Space Administration



NASA Astrophysics

Mario R. Perez

Wilton T. Sanders

Astrophysics

Science Mission Directorate
June 25, 2015

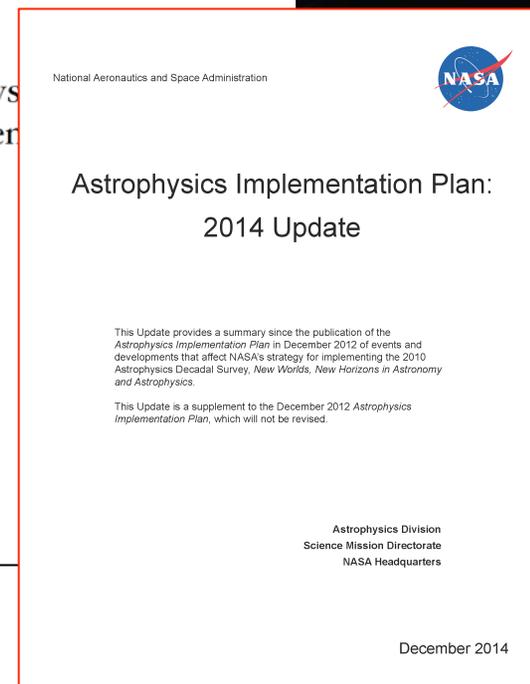
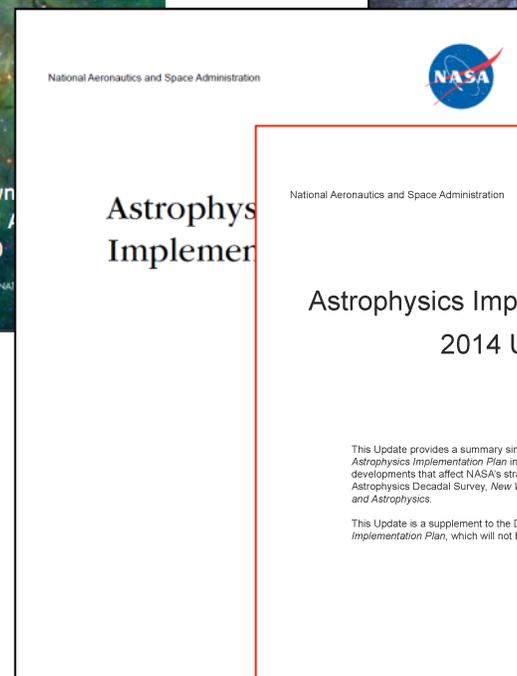
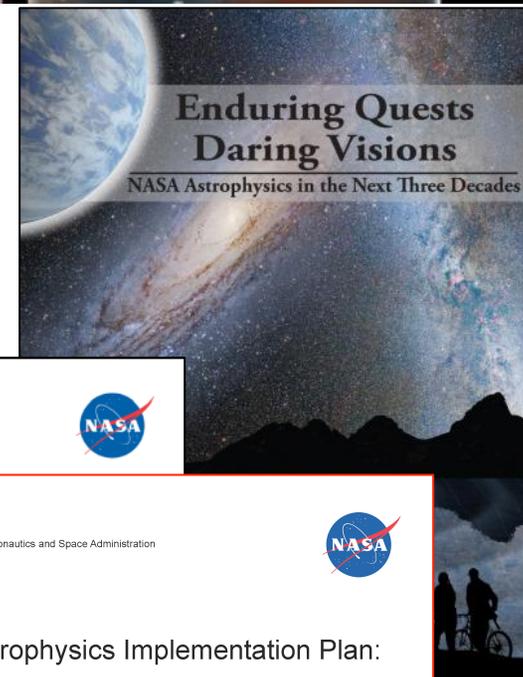
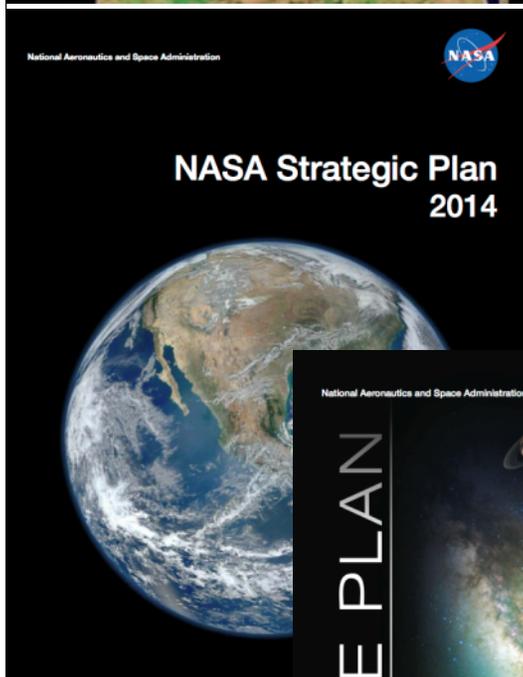


Topics Requested

- SAT & APRA Investments – M. Perez
- Suborbital - W. Sanders
 - Sounding Rockets
 - Balloons (in progress)
- Explorer Program
- Probes Notional Plans
- Others (Q&A)



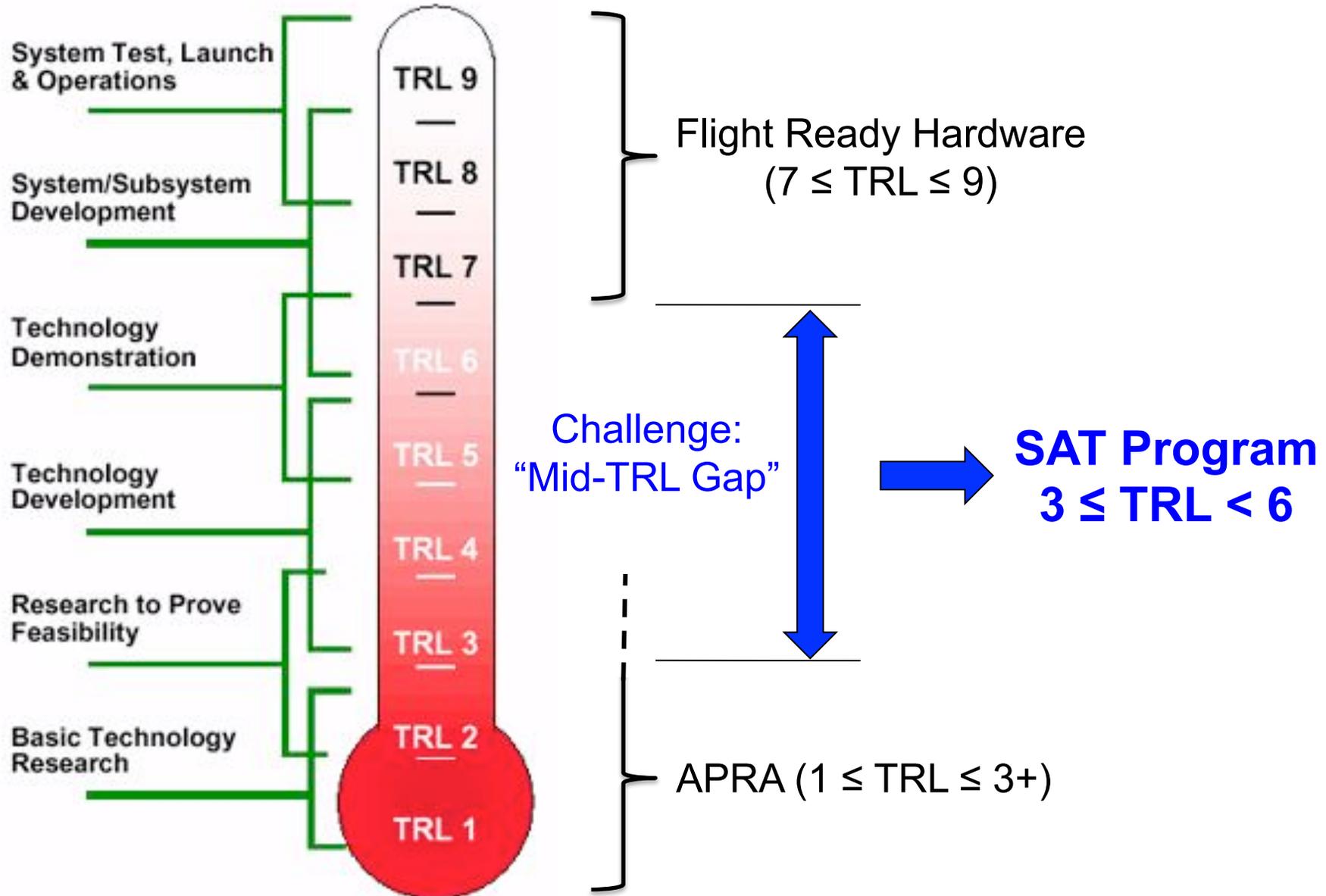
Astrophysics Driving Documents



<http://science.nasa.gov/astrophysics/documents>



Technology Readiness Levels

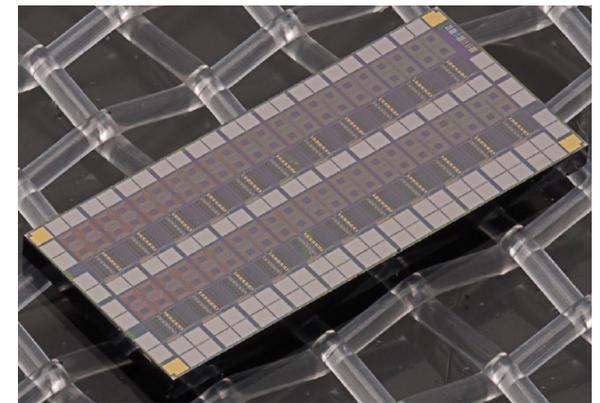




Strategic Astrophysics Technology (SAT)

Areas of emphasis:

- **TDEM**
 - *Starlight Suppression Demonstrations*
 - *Wavefront Sensing and Control of Scattered Light*
 - *System Performance Assessment*
- **TPCOS**
 - *Technologies for X-ray Astrophysics*
 - *Technologies for Gravitational Astrophysics*
 - *Technologies for CMB Polarization Measurements*
- **TCOR**
 - *Detectors (QE < 100%)*
 - *Optical Coatings (R < 100%, AR < 100%)*
 - *Precision Large Optics, Heterodyne Receivers, and Cryocoolers*



Since FY09 – a Total of \$70M has been invested in SAT



Progress Toward Decadal Survey Priorities

The NASA FY15 Appropriation, the President's FY16 Budget Request, and the notional out year budget planning guidance in the President's FY16 Budget Request, support:

Medium-scale 2. Inflation Probe Technology Development Program	Balloon-borne investigations plus strategic astrophysics technology (SAT) investments.
Small-scale. Research Program Augmentations	Increased annual R&A budget by 10% from FY10 to FY12 and another 10% from FY14 to FY16. Within R&A: established Theoretical and Computational Astrophysics Networks (TCAN) program with NSF; funding available for astrophysics theory; funding available for lab astrophysics; funding available for suborbital payloads.
Small-scale. Intermediate Technology development Augmentation	Established competed Strategic Astrophysics Technology (SAT) program element; directed technology funding for WFIRST and other large-scale decadal priorities.
Small-scale. Future Ultraviolet-Visible Space Capability	Strategic Astrophysics Technology (SAT) investments.
Small-scale. SPICA (U.S. contribution to JAXA-led)	Not supported as a strategic contribution; candidate for Explorer Mission of Opportunity.

Starting in FY17 – a Total of \$20M per year will be available



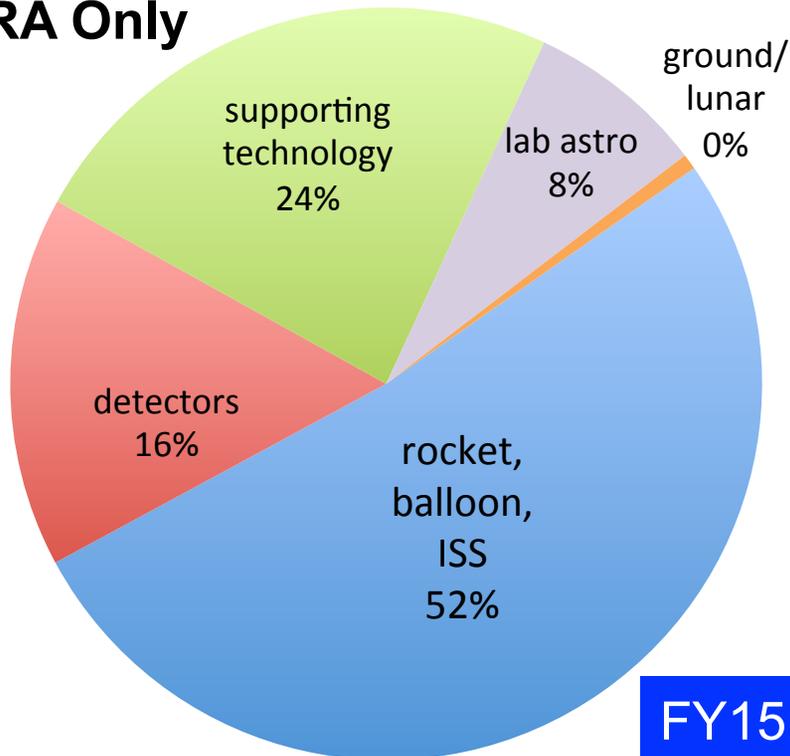
Astrophysics Research Program Funding

Snapshot: Most Recent Year

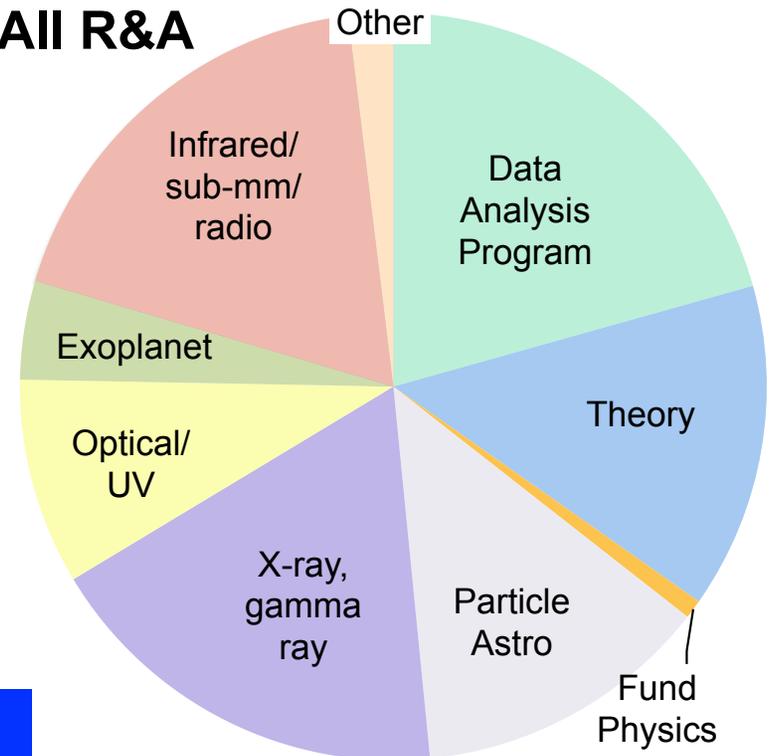
	Proposals Rec'd	Year-1 \$M	Proposals selected	Success Rate	Proposals Rec'd 2015
APRA-13	179	10.0	43	24%	151
SAT-13	18	5.4	10	56%	28
ADAP-14	300	7.5	62	21%	
XRP-14	62	1.3	11	18%	
ATP-14	214	4.7	31	14%	
TOTAL	773	28.9	157	20%	

Does not include RTF, TCAN, WPS, GO programs

APRA Only



All R&A



FY15: \$50M



Decadal Survey 2010 Goals

- **Suborbital Program**

- Increase rate of flights
- Research rockets and orbital rockets
- Long-Duration Balloons (LDBs) and Ultra-Long Duration Balloons (ULDBs)
- Fly Super Pressure Balloons (SPB) from mid-latitudes to include more dark time, an astronomical requirements (e.g., around Australia)



Sounding Rockets

NASA SOUNDING ROCKETS
MISSIONS LAUNCHED
FISCAL YEAR 2015

NASA MISSIONS

NO.	MISSION	DISCIPLINE	EXPERIMENTER	ORGANIZATION	PROJECT	DATE	TIME (Z)	RANGE	FLIGHT RESULTS		
									VEHICLE	PL SUPPORT SYSTEMS	EXPERIMENT
1.	36.253 US	SOLAR & HELIOSPHERIC	HASSLER	SWRI	RAISE	11-06-14	19:07:00	WS	S	S	S
2.	52.001 UE	GEOSPACE SCIENCE	CONDE	U. OF ALASKA/FAIRBANKS	C-REX	11-24-14	08:05:00	NOR	S	S	S
3.	36.295 US	SOLAR & HELIOSPHERIC	KRUCKER	U. OF CA @ BERKELEY	FOXSI	12-11-14	19:11:01	WS	S	S	S
4.	46.009 UE	GEOSPACE SCIENCE	COLLINS	UNIVERSITY OF ALASKA	MTEX	01-26-15	09:13:00	FB	S	S	S
5.	46.010 UE	GEOSPACE SCIENCE	COLLINS	UNIVERSITY OF ALASKA	MTEX	01-26-15	09:46:00	FB	S	S	S
6.	41.111 UE	GEOSPACE SCIENCE	LARSEN	CLEMSON UNIVERSITY	MIST	01-26-15	09:14:00	FB	S	S	S
7.	41.112 UE	GEOSPACE SCIENCE	LARSEN	CLEMSON UNIVERSITY	MIST	01-26-15	09:47:00	FB	S	S	S
8.	49.002 UE	GEOSPACE SCIENCE	SWENSON	UTAH STATE UNIVERSITY	ASSP	01-28-15	10:41:01	FB	S	S	S
9.	46.008 UO	STUDENT OUTREACH	KOEHLER	UNIV. OF COLORADO	ROCKSAT-	04-18-15	11:01:00	WI	S	S	S
10.	36.292 UH	HIGH ENERGY ASTROPHYSICS	MCENTAFFER	UNIVERSITY OF IOWA	OGRESS	05-02-15	08:30:01	WS	S	S	S
11.	36.300 US	GEOSPACE SCIENCE	WOODS	UNIV. OF COLORADO	EVE	05-21-15	19:15:00	WS	F	F	F



Sounding Rockets

JUNE 2015
NASA SOUNDING ROCKETS
CALENDAR YEAR 2015

NASA MISSIONS

<u>NO.</u>	<u>MISSION</u>	<u>DISCIPLINE</u>	<u>EXPERIMENTER</u>	<u>ORGANIZATION</u>	<u>PROJECT</u>	<u>RANGE</u>	<u>DATE</u>	<u>TIME</u>	<u>NASA/NSROC RESPONSIBILITY</u>
1.	41.113 UO	STUDENT OUTREACH	KOEHLER	UNIV. OF COLORADO	ROCKON	WI	JUN-25	DAY	N. EMPSON
2.	36.313 NP	SPECIAL PROJECTS	MILLINER	NASA-WFF		WI	JUL-7	DAY	N. CRANOR
3.	46.012 UO	STUDENT OUTREACH	KOEHLER	UNIV. OF COLORADO	ROCKSAT-X	WI	AUG-11	DAY	B. MCKINLAY
4.	36.282 US	SOLAR & HELIOSPHERIC	KANKELBORG	MONTANA STATE UNIV.	MOSES #2	WS	AUG-20	DAY	N. EMPSON
5.	36.291 US	SOLAR & HELIOSPHERIC	WINEBARGER	U.OF ALABAMA/HUNTSVILLE	CLASP	WS	SEP-3	DAY	B. MCKINLAY
6.	46.011 GP	SPECIAL PROJECTS	MILLINER	NASA-WFF	MUSIC	WI	SEP-11	DAY	J. SCOTT
7.	36.310 GT	TEST & SUPPORT	HESH	NASA-WFF		WI	SEP-16	DAY	N. CRANOR
8.	36.312 UG	UV/OPTICAL ASTROPHYSICS	MCCANDLISS	JHU	FORTIS	WS	OCT-10	DAY	B. MCKINLAY
9.	36.293 UG	UV/OPTICAL ASTROPHYSICS	CHAKRABARTI	U. OF MASS. -LOWELL	PICTURE	WS	OCT-22	DAY	D. JENNINGS
10.	36.307 DS	SOLAR & HELIOSPHERIC	MOSES	NAVAL RESEARCH LAB	HERSCHEL	WS	OCT-31	DAY	T. GASS
11.	52.002 UE	GEOSPACE SCIENCE	LESSARD	UNIV. OF NEW HAMPSHIRE	RENU 2	NOR	NOV-10	NIGHT	J. SCOTT
12.	49.003 UE	GEOSPACE SCIENCE	LABELLE	DARTMOUTH COLLEGE	CAPER	NOR	NOV-10	NIGHT	N. EMPSON
13.	36.297 UG	UV/OPTICAL ASTROPHYSICS	FRANCE	UNIVERSITY OF COLORADO	CHESS-2	WS	NOV-17	DAY	D. JENNINGS
14.	12.078 GT	TEST & SUPPORT	MILLINER	NASA-WFF		WS	DEC-1	DAY	N. CRANOR
15.	36.305 UH	HIGH ENERGY ASTROPHYSICS	GALEAZZI	UNIVERSITY OF MIAMI	DXL-2	WS	DEC-4	DAY	T. GASS



Sounding Rockets

JUNE 2015
NASA SOUNDING ROCKETS
CALENDAR YEAR 2016

NASA MISSIONS

<u>NO.</u>	<u>MISSION</u>	<u>DISCIPLINE</u>	<u>EXPERIMENTER</u>	<u>ORGANIZATION</u>	<u>PROJECT</u>	<u>RANGE</u>	<u>DATE</u>	<u>TIME</u>	<u>NASA/NSROC RESPONSIBILITY</u>
1.	36.302 UE	GEOSPACE SCIENCE	BAILEY	VIRGINIA TECH	POLARNOX	FB	JAN-21	NIGHT	B. MCKINLAY
2.	36.262 UG	UV/OPTICAL ASTROPHYSICS	KAISER	JHU	ACCESS #1	WS	JAN-19	NIGHT	D. JENNINGS
3.	36.301 GE	GEOSPACE SCIENCE	PFAFF	GSFC		FB	JAN-28	NIGHT	N. CRANOR
4.	36.306 GE	GEOSPACE SCIENCE	PFAFF	GSFC		FB	JAN-28	NIGHT	N. CRANOR
5.	41.114 NP	SPECIAL PROJECTS	DELEON	NASA-ARC		WI	JAN-28	DAY	N. CRANOR
6.	36.303 UE	GEOSPACE SCIENCE	LYNCH	DARTMOUTH COLLEGE	ISINGLASS	FB	FEB-1	NIGHT	J. SCOTT
7.	36.304 UE	GEOSPACE SCIENCE	LYNCH	DARTMOUTH COLLEGE	ISINGLASS	FB	FEB-1	NIGHT	J. SCOTT
8.	36.309 US	SOLAR & HELIOSPHERIC	HASSLER	SWRI	RAISE	WS	MAR-1	DAY	N. CRANOR
9.	36.245 UH	HIGH ENERGY ASTROPHYSICS	FIGUEROA	MIT	MICRO-X	WS	MAR-15	NIGHT	T. GASS
10.	36.314 NS	SOLAR & HELIOSPHERIC	CIRTAİN	NASA/MSFC	HiC	WS	JUN-23	DAY	N. EMPSON
11.	36.281 UE	GEOSPACE SCIENCE	BOCK	CAL TECH	CIBER-2	WS	JUL-1	NIGHT	D. JENNINGS
12.	36.259 GH	HIGH ENERGY ASTROPHYSICS	GENDREAU	NASA-GSFC	XACT 1	WS	DEC-1	DAY	N. EMPSON



Sounding Rockets

JUNE 2015
NASA SOUNDING ROCKETS
CALENDAR YEAR 2017

NASA MISSIONS

<u>NO.</u>	<u>MISSION</u>	<u>DISCIPLINE</u>	<u>EXPERIMENTER</u>	<u>ORGANIZATION</u>	<u>PROJECT</u>	<u>RANGE</u>	<u>DATE</u>	<u>TIME</u>	<u>NASA/NSROC RESPONSIBILITY</u>
1.	36.315 UE	GEOSPACE SCIENCES	LARSEN	CLEMSON UNIVERSITY	AZURE	FB	MAR-1	NIGHT	J. SCOTT
2.	36.316 UE	GEOSPACE SCIENCES	LARSEN	CLEMSON UNIVERSITY	AZURE	FB	MAR-1	NIGHT	J. SCOTT
3.	46.013 UE	GEOSPACE SCIENCES	HYSELL	CORNELL UNIVERSITY	WINDY	KWAJ	AUG-1	TBD	T. GASS
4.	41.115 UE	GEOSPACE SCIENCES	HYSELL	CORNELL UNIVERSITY	WINDY	KWAJ	AUG-1	TBD	T. GASS
5.	36.111 UG	UV/OPTICAL ASTROPHYSICS	GREEN	UNIV. OF COLORADO	DUECE	WS	OCT-30	DAY	MCKINLAY

JUNE 2015
NASA SOUNDING ROCKETS
CALENDAR YEAR 2018

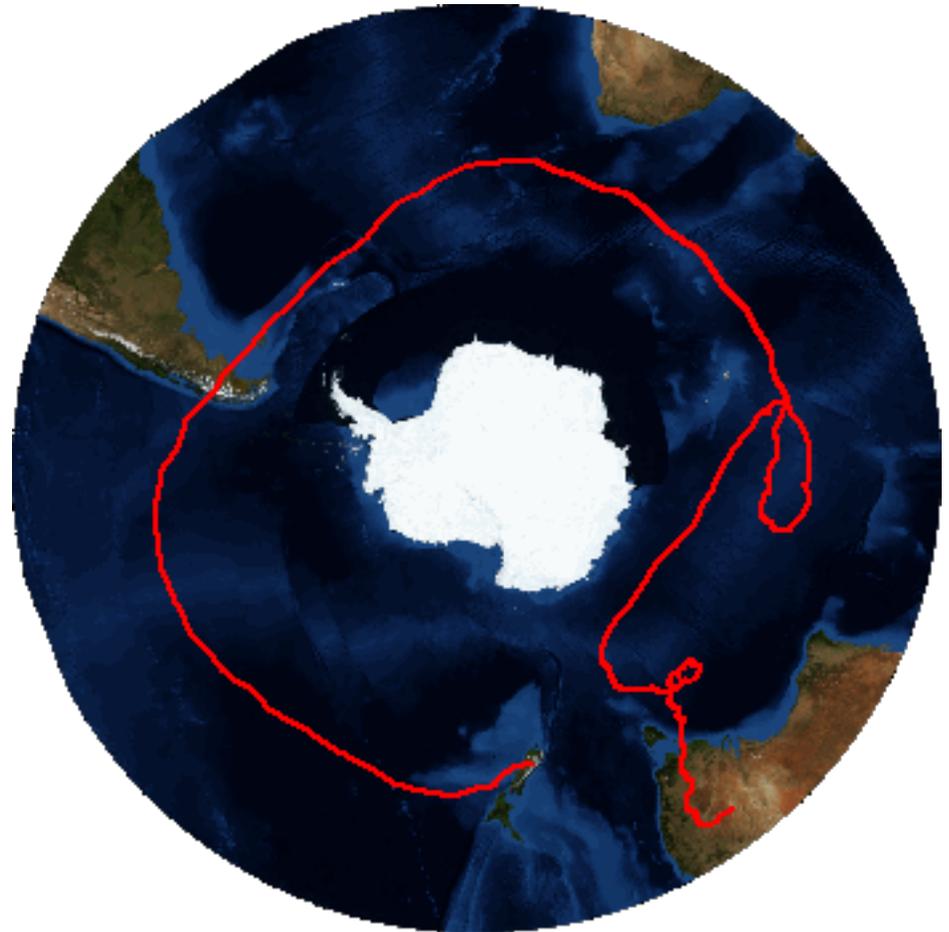
NASA MISSIONS

<u>NO.</u>	<u>MISSION</u>	<u>DISCIPLINE</u>	<u>EXPERIMENTER</u>	<u>ORGANIZATION</u>	<u>PROJECT</u>	<u>RANGE</u>	<u>DATE</u>	<u>TIME</u>	<u>NASA/NSROC RESPONSIBILITY</u>
1.	36.298 UH	HIGH ENERGY ASTROPHYSICS	MCENTAFFER	UNIVERSITY OF IOWA	OGRE	FB	JAN-1	DAY	N. EMPSON



Balloons

NASA Super Pressure Balloon was launched from New Zealand on March 26 and flew for 32 days until April 27, 2015. It was terminated over central Australia. Maintained a constant float altitude of 110,000 feet with a test payload of 5,000 lb.







Funded Payloads

BETTI - Stephen Rinehart – NASA/GSFC (not flown yet)

FIREBALL2 – Chris Martin – Caltech (not flown yet)

PIPER – Al Kogut – NASA/GSFC (not flown yet)

ASCOT – Peter Bloser – U. New Hampshire (not flown yet)

ANITA – Peter Gorham – U. Hawaii

NCT – Steve Boggs, U. California, Berkeley

SPIDER – Bill Jones – Princeton U.

BLAST – Mark Devlin – U. Pennsylvania

EBEX – Shaul Hanny – U. Minnesota

Super TIGER – Bob Binns – Washington U.

CREAM – Eun-Suk Seo – U. Maryland (now an ISS payload)

STO – Chris Walker – U. Arizona

X-Calibur/InFOC_μS – Krawczynski/Okajima – Washington U./GSFC

GRAPE – Mark McConnell – U. New Hampshire



ANITA-3 science in the community



- • Askaryan effect (SLAC 2001-2007)
 - Coherent Cherenkov emission from cascades in ice
- • Enables utilization of entire Antarctic ice sheet as a potential neutrino detector
- • ‘Geosynchrotron’ emission
 - Curvature radiation from UHECR air showers in Antarctic geomagnetic field (strongest, most vertical on Earth!)
- • ANITA sees these UHE cosmic ray radio impulses in reflection off Antarctic surface



Progress Toward Decadal Survey Priorities

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Small-scale. Future Ultraviolet-Visible Space Capability

Strategic Astrophysics Technology (SAT) investments.

Small-scale. SPICA (U.S. contribution to JAXA-led)

Not supported as a strategic contribution; candidate for Explorer Mission of Opportunity.



2014 Astrophysics Explorers AO

- AO released September 17, 2014.
 - Small Explorer (SMEX), cost cap \$175M including LV
 - Mission(s) of Opportunity, cost cap \$65M for space, \$35M for suborbital-class
 - US Participating Investigators
- Notice of intent were due October 15, 2014.
 - NASA received ~30 NOIs
- Proposals received December 18, 2014.
 - NASA received ~25 proposals (total of all three categories)
- Step 1 Selections expected ~ Summer 2015.
- Step 2 Downselections expected ~ early 2017.
- Launch Readiness Date NLT end of 2020.

For additional info: <http://explorers.larc.nasa.gov/APSMEX/>



Progress Toward Decadal Survey Priorities

The NASA FY15 Appropriation, the President's FY16 Budget Request, and the notional out year budget planning guidance in the President's FY16 Budget Request, support:

Large-scale 1. WFIRST	Preformulation and focused technology development for WFIRST/AFTA (a 2.4m version of WFIRST with a coronagraph) are underway to enable a new start NET FY2017. Budget line established for an Astrophysics Decadal Strategic Mission.
Large-scale 2. Augmentation to Explorer Program	Astrophysics Explorers planned budget increased to support decadal cadence of AOs including SMEX AO in Fall 2014 and MIDEX AO in late 2016/early 2017.
Large-scale 3. LISA	Discussing partnership on ESA's L3 gravitational wave observatory and participating in ESA-led assessments in 2014-2015. Strategic astrophysics technology (SAT) investments plus support of LISA Pathfinder.
Large-scale 4. IXO	NASA is pursuing a partnership on ESA's L2 Athena X-ray observatory; the Athena study phase, with U.S. participation, is underway. Strategic astrophysics technology (SAT) investments.
Medium-scale 1. New Worlds Technology Development Program	Focused technology development for a coronagraph on WFIRST, strategic astrophysics technology (SAT) investments, and exoplanet probe mission concept studies. Established partnership with NSF to develop extreme precision Doppler spectrometer as facility instrument. Exozodi survey using LBTI.



Preparing for the 2020 Decadal Survey Thinking about Probes

- What was done 10 years ago?
 - Origins Probes Mission Concepts (2004)
 - ROSES call for quick (~9 month) paper concept studies
 - ~9 concepts selected in 2004; total funding ~\$1M (\$100K average)
 - Astrophysics Mission Concepts Study (AMCS; 2007)
 - ROSES call for ~1 year paper concept studies
 - Nineteen (+1) ASMC concepts selected in 2007; total funding \$13M (\$700K average)
 - Was this effective? Efficient? Appropriately impactful?
- Possibilities this time
 - Real mission concept studies
 - Just like we are doing for large mission concepts
 - How would we select them? Where does funding come from?
 - Paper mission concept studies
 - Just like AMCS, but limited to Probes
 - Self selected, self funded
 - Anybody can submit a white paper to the 2020 Decadal Survey
- Awaiting input from the PAG reports



Preparing for the 2020 Decadal Survey Medium-class (Probe) Concepts

Probe-class (medium size) mission concepts

- No decision has been made by NASA at this time on how to provide input to the 2020 Decadal Survey Committee regarding probe-class missions.
- There are multiple paths to identifying probe-class mission concepts, and none have been precluded at this time.
- Each of the STDTs for large mission concepts will be challenged to identify one or more probe-class versions of their mission and to estimate the percentage of the original science case that can be achieved.
- The Mid-Decade Review may provide recommendations to NASA regarding the value of probe-class mission concept studies in advance of the 2020 Decadal Survey.
- Should NASA conduct stand-alone probe-class mission concept studies, they would be initiated no earlier than FY2017.



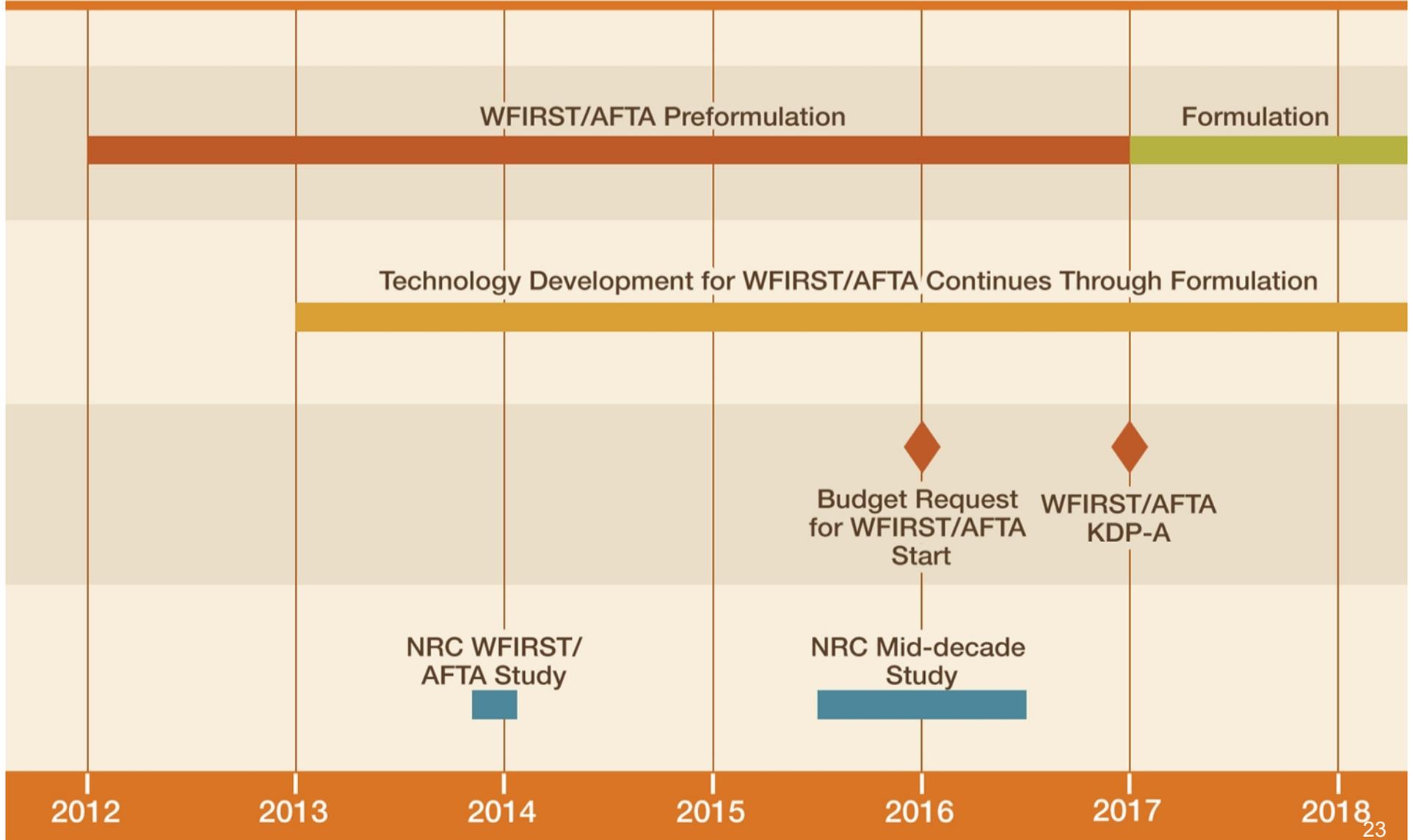
Backups



Plan for WFIRST/AFTA Preformulation

Widefield Infrared Survey Telescope using Astrophysics Focused Telescope Assets

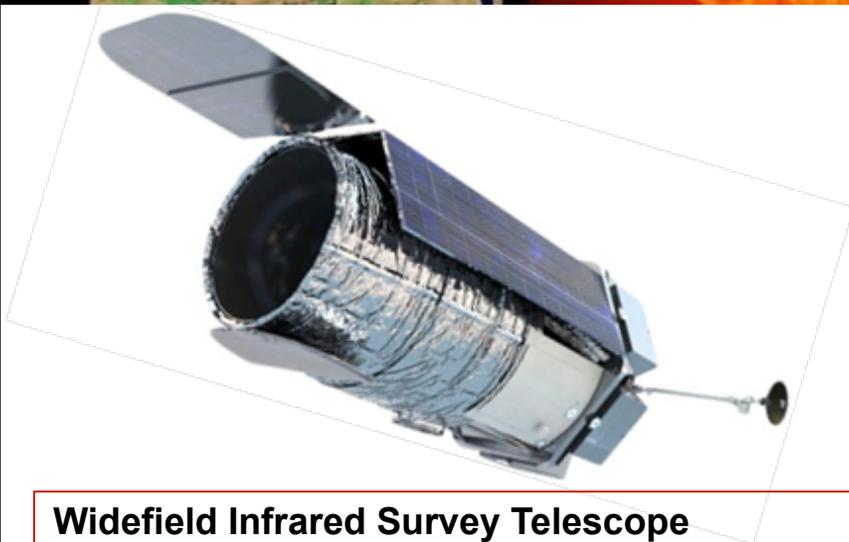
WFIRST/AFTA timeline





WFIRST / AFTA

Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets



Widefield Infrared Survey Telescope

Top priority of 2010 Decadal Survey

Science themes: Dark Energy, Exoplanets, Large Area Near Infrared Surveys

Mission: 2.4m widefield telescope at GEO, uses existing AFTA hardware to image 0.28 deg² at 0.8-2.0 μm

Instruments (design reference mission):

Wide Field Instrument, Coronagraph

Instrument

- FY15 Appropriation and FY16 Budget Request support pre-formulation of WFIRST/AFTA
- Plans support Agency/Administration decision for formulation to begin NET FY 2017, should funding be available.

<http://wfirst.gsfc.nasa.gov/>

CURRENT STATUS:

- May 2013, NASA Administrator Bolden directed study of WFIRST/AFTA and preserve option for FY17 new start if budget is available.
 - No decision expected before early CY 2016.
- Currently in pre-formulation phase.
 - Activities include technology development for detectors and coronagraph (with STMD), assessment of the 2.4m telescopes including risk mitigation, mission design trades, payload accommodation studies, and observatory performance simulations.
- Maturing key technologies by FY19.
 - H4RG infrared detectors for widefield imager.
 - Internal coronagraph for exoplanet characterization (two architectures identified December 2013; occulting mask coronagraph and phased induced amplitude apodization complex mask coronagraph).
- March 2014 NRC study on WFIRST/AFTA offers positive view of AFTA, with concerns about technology and cost risks.
- March 2015 SDT report with design reference mission presents baseline plan for WFIRST/AFTA
- WFIRST Preparatory Science funds 17 ROSES proposals that are relevant to WFIRST's goals and WFIRST-specific simulations and models.



WFIRST / AFTA

Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets

Coronagraph Technology Milestones

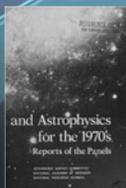
1	Shaped Pupil mask fabricated with reflectivity of 10^{-4} and 20 μm pixel size.	7/21/14 ✓
2	Shaped Pupil Coronagraph demos 10^{-8} raw contrast with narrowband light.	9/30/14 ✓
3	PIAACMC mask fabricated with 10^{-8} raw contrast with 10% broadband light.	12/15/14 ✓
4	Hybrid Lyot Coronagraph demos 10^{-8} raw contrast with narrowband light..	2/28/15 ✓
5	Occulting Mask Coronagraph demos 10^{-8} raw contrast with 10% broadband light.	9/15/15
6	Low Order Wavefront Sensing provides jitter sensing better than 0.4 mas rms.	9/30/15
7	Spectrograph read-out demo to have low dark current and read noise.	8/25/16
8	PIAACMC coronagraph demos 10^{-8} raw contrast with 10% broadband light.	9/30/16
9	Occulting Mask Coronagraph demos 10^{-8} raw contrast with 10% broadband light.	9/30/16

Widefield Detector Technology Milestones

1	Produce, test, and analyze 2 candidate passivation techniques in banded arrays.	7/31/14 ✓
2	Produce, test, and analyze 1 additional candidate passivation techniques in banded arrays.	12/30/14 ✓
3	Produce, test, and analyze full arrays with operability > 95%.	9/15/15
4	Produce, test, and analyze final selected recipe in full arrays demonstrating a yield > 20% with operability > 95%.	9/15/16
5	Complete environmental testing of one sensor chip assembly, as per NASA test standards.	12/1/16

ASTROPHYSICS

Decadal Survey Missions



1972
Decadal
Survey
Hubble



1982
Decadal
Survey
Chandra



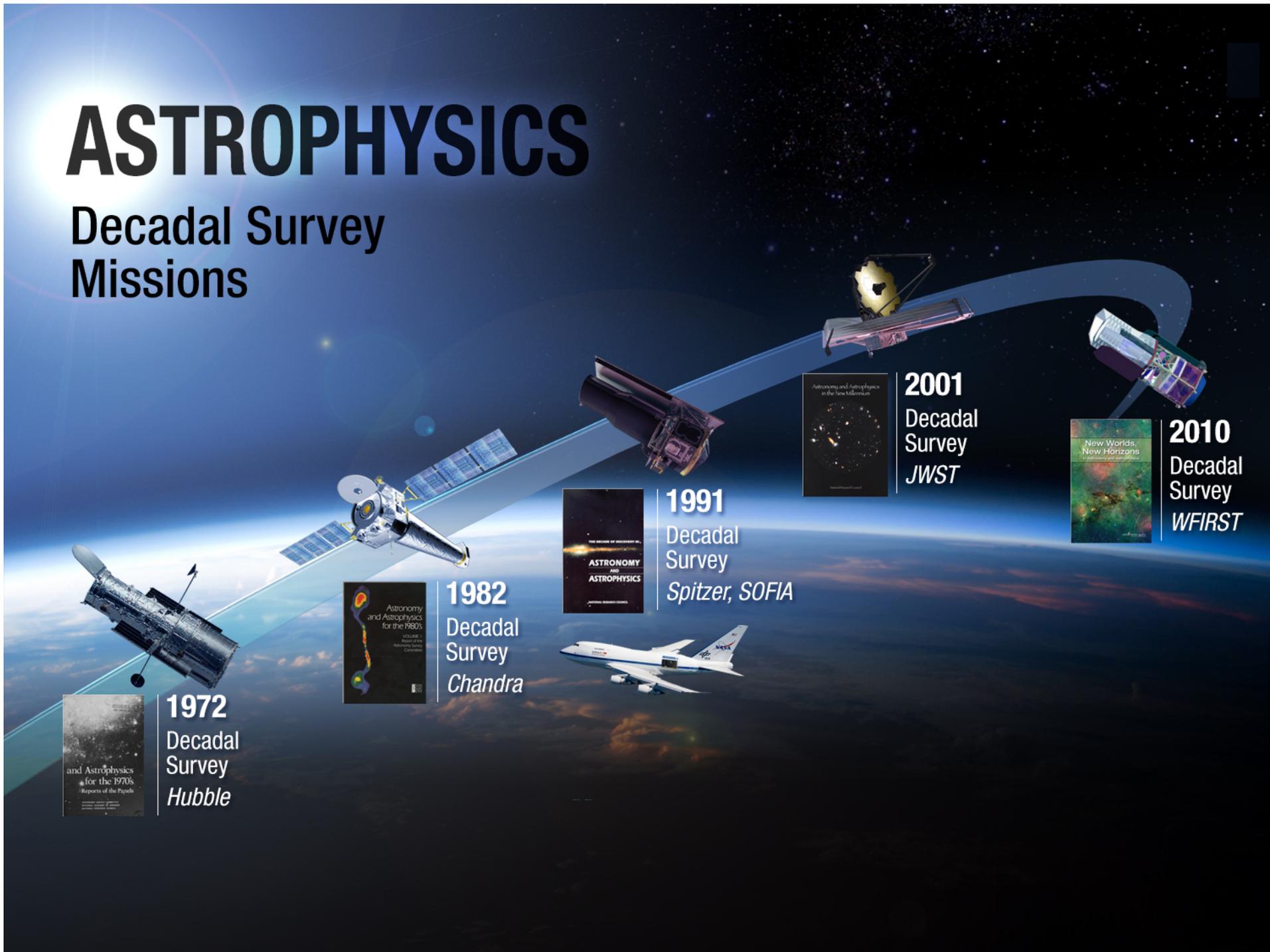
1991
Decadal
Survey
Spitzer, SOFIA



2001
Decadal
Survey
JWST



2010
Decadal
Survey
WFIRST





Preparing for the 2020 Decadal Survey Large Mission Concepts

The initial short list (in alphabetical order):

- **FAR IR Surveyor** – The Astrophysics Visionary Roadmap identifies a Far IR Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.
- **Habitable-Exoplanet Imaging Mission** – The 2010 Decadal Survey recommends that a habitable-exoplanet imaging mission be studied in time for consideration by the 2020 decadal survey.
- **UV/Optical/IR Surveyor** – The Astrophysics Visionary Roadmap identifies a UV/Optical/IR Surveyor as contributing through improvements in sensitivity, spectroscopy, high contrast imaging, astrometry, angular resolution and/or wavelength coverage. The 2010 Decadal Survey recommends that NASA prepare for a UV mission to be considered by the 2020 Decadal Survey.
- **X-ray Surveyor** – The Astrophysics Visionary Roadmap identifies an X-ray Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.